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(54) Title:  **$\alpha$ -1-ANTICHYMOTRYPSIN ANALOGUES HAVING CHYMASE INHIBITING ACTIVITY**

## (57) Abstract

The invention provides analogues of  $\alpha$ -1-antichymotrypsin having amino acid substitutions at position 358.  $\alpha$ -1-antichymotrypsin analogues having amino acid substitutions at positions 356-361 and analogues having amino acid substitutions at positions 356-361 wherein the amino acid at position 358 is substituted are also within the scope of the invention. These analogues exhibit chymase inhibitory activity. Also provided are novel  $\alpha$ -1-antichymotrypsins having an N-terminal extension of methionine-alanine-serine or alanine-serine. Expression vectors for the production of  $\alpha$ -1-antichymotrypsins are also provided. The present invention also provides host cells and cell cultures capable of expressing analogues of  $\alpha$ -1-antichymotrypsin, as well as protein preparations from the host cells. Methods of producing and using the analogues of  $\alpha$ -1-antichymotrypsin to inhibit chymase activity are also provided.

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**$\alpha$ -1-ANTICHYTRYPSIN ANALOGUES HAVING  
CHYMASE INHIBITING ACTIVITY**

**REFERENCE TO RELATED APPLICATIONS**

The present application is a continuation-in-part  
5 of U.S. Patent Application Serial No. UPN-0964, filed  
concurrently herewith, the concurrently filed applications  
are continuations-in-part of U.S. Patent Application Serial  
No. 08/005,898, and U.S. Patent Application Serial No.  
08/005,908, filed January 15, 1993, which are divisionals  
10 of U.S. Patent Application Serial No. 735,322, filed July  
24, 1991, now U.S. Patent 5,266,465, which is in turn a  
divisional application of U.S. Patent Application Serial  
No. 370,704 filed June 23, 1989, which is now U.S. Patent  
5,079,336. The disclosures of each of these applications  
15 is hereby incorporated by reference.

**REFERENCE TO GOVERNMENT GRANTS**

The work for the present invention was supported  
in part by National Institutes of Health grants AG-10599  
and AR-39674. The United States government may have  
20 certain rights in the invention.

**FIELD OF THE INVENTION**

This invention is related to the field of  
substances produced by recombinant DNA technology and more  
25 particularly to the field of proteins produced by  
recombinant DNA technology.

**BACKGROUND OF THE INVENTION**

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The interaction of serine protease inhibitors, serpins (serpin - serine proteinase inhibitor), with endogenous and microbial proteases produces a spectrum of molecular species each of which are components of a highly 5 evolutionarily conserved homeostatic mechanism that operates to maintain a concentration of intact, active serpins pivotal in host survival. Of these species, the serpin-enzyme complex and the hydrolyzed, inactive form of the intact serpin stimulate the production of IL-6, 10 signaling hepatocytes to increase synthesis of the acute phase proteins including a subpopulation of the serpin superfamily of proteins. Although serpin-enzyme complexes are rapidly cleared from the circulation, they may accumulate along with the cleaved and intact forms in local 15 areas of inflammation. This establishes a complex microenvironment of chemoattractants and inhibitors of chemotaxis as well as activators and inhibitors of neutrophil degranulation, leukotriene, platelet activating factor (PAF) and superoxide production. Kilpatrick et al. 20 have shown that native antichymotrypsin (ACT) and recombinant antichymotrypsin (rACT) inhibited superoxide generation by human neutrophils in suspension. Kilpatrick et al., *J. Immunol.*, 1991, 146, 2388. In this system, intact ACT and rACT complexed with chymotrypsin (Chtr) were 25 equally effective in inhibiting free radical production by neutrophils stimulated with f-Met-Leu-Phe, Concanavalin A (ConA) or phorbol myristate acetate (PMA).

A variety of animal models corroborate the hypothesis that runaway serine protease activity is a major 30 mechanism of lung injury and that an appropriate serpin response controls the degree of the injury. For example, antithrombin III (ATIII) in combination with alpha-1- protease inhibitor ( $\alpha$ 1PI), protected sheep from endotoxin-induced lung injury where the individual serpins were not 35 as effective as the combination. Redens et al., *Circ. Shock*, 1988, 26, 15. Redens et al. also showed that ATIII protects against the development of disseminated

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intravascular coagulation in endotoxemic rats. Emerson et al., *Circ. Shock*, 1987, 21, 1. A scavenger of H<sub>2</sub>O<sub>2</sub> and a chloromethyl ketone inhibitor of elastase blocked reactive oxygen potentiation of neutrophil elastase-mediated acute 5 edematous lung injury in a rat and  $\alpha$ 1PI diminished bleomycin-mediated pulmonary inflammation as well as subsequent fibrosis. Baird et al., *Physiol.*, 1986, 61, 2224 and Nagai et al., *Am. Rev. Resp. Dis.*, 1992, 145, 651. While in another system, however, neutrophil elastase 10 inhibitors, Eglin C and a low molecular weight compound L 658,758, failed to inhibit leukotriene B4 (LTB4)-induced neutrophil-mediated adherence, diapedesis or vascular leakage. Rosengren et al., *Am. J. Physiol.*, 1990, 259, H1288.

15 Accordingly, inhibitors of proteolytic enzymes administered therapeutically may limit the molecular and cellular mechanisms of inflammation and reduce tissue damage. Therefore, there remains a need for safe and effective inhibitors such as  $\alpha$ -1-antichymotrypsin for 20 clinical applications in animals. Therapeutic agents based on multifunctional protease inhibitors will clinically advance therapy of diseases where free radicals as well as proteases have been implicated in the mechanism of injury such as the adult respiratory syndrome, pancreatitis, 25 inflammatory skin lesions and reperfusion injury.

#### SUMMARY OF THE INVENTION

The present invention provides analogues of human  $\alpha$ -1-antichymotrypsin having antichymotrypsin activity and/or chymase inhibitory activity. The present invention 30 includes  $\alpha$ -1-antichymotrypsin analogues having an amino acid substitution at position 358 such that the wild type position 358, leucine, is changed to an amino acid selected from tryptophan, alanine, asparagine, aspartic acid, cysteine, glutamine, glutamic acid, glycine, histidine, 35 isoleucine, lysine, methionine, phenylalanine, proline, serine, threonine, tyrosine, and valine. Also included in

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the scope of the present invention is an analogue of human  $\alpha$ -1-antichymotrypsin wherein the amino acids corresponding to the amino acids Thr-Leu-Leu-Ser-Ala-Leu (SEQ ID NO: 7) at positions 356 to 361 of wild-type  $\alpha$ -1-antichymotrypsin 5 are substituted with amino acids Ile-Pro-Xxx-Ser-Ile-Pro (SEQ ID NO: 8). SEQ ID NO: 8 may also be substituted at position 358 with an amino acid selected from the group set forth above.

The novel polypeptides indicated above, as well 10 as human wild type  $\alpha$ -1-antichymotrypsin, Figure 1, may have an N-terminal extension sequence of methionine-alanine-serine or alanine-serine. The novel polypeptides having an N-terminal extension are produced from the nucleotide sequence encoding the entire amino acid sequence of mature 15 human wild type  $\alpha$ -1-antichymotrypsin, optionally having one of the substitutions indicated above, with an N-terminal extension sequence of methionine-alanine-serine or alanine-serine.

These novel  $\alpha$ -1-antichymotrypsin analogues result 20 in stable  $\alpha$ -1-antichymotrypsin monomers and eliminates an N-terminal cysteine present in the rACT described precursor  $\alpha$ -1-antichymotrypsin polypeptide that gave rise to protein dimers and apparent heterogeneity. These  $\alpha$ -1-antichymotrypsin polypeptides have antichymotrypsin 25 activity and are useful in the same manner as  $\alpha$ -1-antichymotrypsin itself. The analogues of the present invention are also useful for chymase inhibition.

The present invention also provides expression vectors comprising nucleic acid sequences coding for the  $\alpha$ -30 1-antichymotrypsin analogues of the invention, transformed host cells and cell cultures capable of expressing the analogues of the invention. The present invention further provides methods of producing  $\alpha$ -1-antichymotrypsin analogues comprising culturing a host cell capable of 35 expressing  $\alpha$ -1-antichymotrypsin analogues.

The present invention also provides methods of inhibiting chymase comprising contacting chymase with an

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inhibitory amount of at least one  $\alpha$ -1-antichymotrypsin analogue. A method of using  $\alpha$ -1-antichymotrypsin analogues to inhibit chymase activity comprising adding an effective amount of an  $\alpha$ -1-antichymotrypsin analogue of the invention 5 to a sample exhibiting chymase activity is also provided.

The scope of the present invention provides analogues of human wild type  $\alpha$ -1-antichymotrypsin which are useful in the treatment of lung inflammation, reperfusion 10 injury, and treating and preventing blood clots.

10 Medicaments and compositions comprising analogues of human wild type  $\alpha$ -1-antichymotrypsin in pharmaceutically acceptable amounts together with a carrier are also the subject of the present invention, as are their uses in 15 treating the conditions identified above.

15 This invention is more particularly pointed out in the appended claims and is described in its preferred embodiments in the following description.

#### **BRIEF DESCRIPTION OF THE FIGURES**

Figure 1 shows the complete nucleotide sequence 20 and predicted amino acid sequence of human wild type  $\alpha$ -1-antichymotrypsin. The full length gene is encoded by nucleotide residues 1-1209.

Figure 2 is a graph of the titration of human chymase with  $\alpha$ -1-antichymotrypsin analogues.

#### **25 DETAILED DESCRIPTION OF THE INVENTION**

The present invention provides analogues of human  $\alpha$ -1-antichymotrypsin wherein the amino acid corresponding to leucine at amino acid position 358 of wild type human  $\alpha$ -1-antichymotrypsin is substituted with an amino acid 30 selected from tryptophan, alanine, asparagine, aspartic acid, cysteine, glutamine, glutamic acid, glycine, histidine, isoleucine, lysine, methionine, phenylalanine, proline, serine, threonine, tyrosine, and valine. In a preferred embodiment of the invention, leucine at position 35 358 is substituted with tryptophan.

An analogue of  $\alpha$ -1-antichymotrypsin wherein amino acids Thr-Leu-Leu-Ser-Ala-Leu (SEQ ID NO: 7) at positions 356-361 are substituted with Ile-Pro-Xxx-Ser-Ile-Pro (SEQ ID NO: 8) is also provided by the present invention. The 5 analogues having amino acid substitutions at positions 356-361 may be substituted at position 358 with an amino acid selected from the group consisting of methionine, tryptophan, alanine, asparagine, aspartic acid, cysteine, glutamine, glutamic acid, glycine, histidine, isoleucine, 10 lysine, phenylalanine, proline, serine, threonine, tyrosine, and valine.

Wild type antichymotrypsin having alterations in the amino acid leucine at position 358 results in analogues referred to as rACT-L358 followed by the one letter amino 15 acid symbol substituted in a particular analogue. For example, rACT-L358W represents recombinant  $\alpha$ -1-antichymotrypsin having tryptophan at amino acid position 358.

Another aspect of the invention provides human  $\alpha$ -20 1-antichymotrypsin, in wild type and analogue forms, having an N-terminal extension of Met-Ala-Ser. In this embodiment of the invention, mature human  $\alpha$ -1-antichymotrypsin contains three additional amino acids at the N-terminus, Met-Ala-Ser. Another embodiment comprises mature human  $\alpha$ -25 1-antichymotrypsin, in wild type and analogue forms, with Met cleaved and two amino acids, Ala-Ser, remaining at the N-terminus. Wild type and analogue forms of  $\alpha$ -1-antichymotrypsin may have the N terminal extensions disclosed herein.

30  $\alpha$ -1-Antichymotrypsin is a serine protease inhibitor (serpin). In its native, circulating form, it is a glycoprotein of between 55,000 and 66,000 daltons, with the variation attributed to microheterogeneity in glycosylation. It is synthesized predominantly in the 35 liver and has also been reported in mast cells, sinus histiocytes, endothelial cells and in cells of the histio/monocytic line. In response to inflammatory

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stimuli, plasma levels of  $\alpha$ -1-antichymotrypsin increase more than four-fold within several hours.

Chymotrypsin-like enzymes and their inhibitors have been identified in a wide variety of normal and 5 abnormal biological processes including modulation of cellular functions, DNA-binding, inhibition of certain parasite functions and processing of vasoconstrictor proteins. In addition,  $\alpha$ -1-antichymotrypsin appears to be a component of the amyloid deposit in Alzheimer's plaques 10 and is present in various carcinomas and in some tissues of the reproductive system.

Human  $\alpha$ -1-antichymotrypsin forms sodium dodecyl sulfate (SDS)-stable complexes with its target enzymes, which is a general property of serpin/serine protease 15 interactions. Very little is known about the nature of these complexes. Although high-resolution crystal structures of chymotrypsin and chymotrypsin/small molecular inhibitor complexes have been resolved and NMR analyses of the enzyme have been reported, no direct structural studies 20 of human  $\alpha$ -1-antichymotrypsin alone or as a complex with a serine protease have been reported.

There is evidence that proteases and oxidants play a central role in establishing and maintaining shock physiology and that protease inhibitors can favorably 25 modify the outcome of shock. Small molecule protease inhibitors have been shown to have efficacy in pancreatitis in humans. Similarly, antichymotrypsins may be implicated in treatment of coagulation disorders as in liver diseases. Proteases are also important mediators of inflammatory 30 diseases. Regulation of these enzymes by their inhibitors is critical for the control of tissue destruction in these diseases.

The analogues of the invention, having an amino acid substitution at amino acid position 358, the analogues 35 having amino acids substitutions at amino acid positions 356-361 of wild-type  $\alpha$ -1-antichymotrypsin with position 358 having an amino acid selected from the amino acids set

forth above, are surprisingly and unexpectedly much better inhibitors of chymase, a proteinase stored at high concentrations within human mast cells, than wild-type or native antichymotrypsin. Human chymase is inhibited by two 5 human serpin plasma inhibitors,  $\alpha$ -1-antichymotrypsin and  $\alpha$ -1-proteinase inhibitor. Both of these inhibitors are members of the serpin protein family. Although inhibition of chymase appeared irreversible with  $\alpha$ -1-antichymotrypsin and  $\alpha$ -1-proteinase inhibitor, showing the typical tight- 10 binding complex resistant to denaturation in SDS, reactions with both inhibitors were not highly efficient. Determined under pseudo first order conditions, second order rate constants of 25,000 and 8,000  $M^{-1}S^{-1}$  were obtained for  $\alpha$ -1-antichymotrypsin and  $\alpha$ -1-proteinase inhibitor, 15 respectively. These values are approximately 100 to 1,000 fold lower than the values observed for the inhibition of neutrophil cathepsin G by  $\alpha$ -1-antichymotrypsin, or the inhibition of neutrophil elastase by  $\alpha$ -1-proteinase inhibitor. The inefficiency of the reaction was even more 20 evident in titrations where endpoints yielded stoichiometries of inhibition (SI) of 4.5 ( $\alpha$ -1-antichymotrypsin) and 5.0 ( $\alpha$ -1-proteinase inhibitor) moles of inhibitor/mole of chymase. Analysis of these reactions by SDS-PAGE and by N-terminal sequence analysis of products 25 indicated that the high stoichiometries of inhibition were due to a competing reaction producing a degraded inhibitor by hydrolysis within the reactive loop of the inhibitor.

The  $\alpha$ -1-antichymotrypsin analogue wherein the leucine at position 358 of wild-type  $\alpha$ -1-antichymotrypsin 30 is substituted with tryptophan is a much more efficient inhibitor of chymase than the natural inhibitors. The stoichiometry of inhibition of approximately 1 mole of inhibitor/mole of chymase. Thus, the competing cleavage reaction is nearly eliminated, indicating that the 35 analogues of the invention are four-fold more efficient for inhibition of chymase than wild type  $\alpha$ -1-antichymotrypsin. The apparent second order rate constant for inhibition is

more than five-fold greater than the apparent second order rate constant for inhibition of chymase by wild type  $\alpha$ -1-antichymotrypsin, rACT, demonstrating a faster interaction.

Another aspect of the present invention provides 5 nucleic acid sequences coding for  $\alpha$ -1-antichymotrypsin and analogues, expression vectors and host cells transformed to express the nucleic acid sequences of the invention, protein preparations comprising the proteins of the present invention synthesized in a host cell transformed with a DNA 10 sequence encoding the protein and cell cultures capable of expressing the nucleic acid sequence of the invention.

Generally,  $\alpha$ -1-antichymotrypsin analogues, having amino acid substitutions at amino acid position 358 or having amino acid substitutions at amino acid positions 15 356-361 in the wild-type  $\alpha$ -1-antichymotrypsin with position 358 having an amino acid selected from the amino acids identified above, are produced in host cells that have been transformed with an expression vector comprising a nucleic acid sequence coding for the particular protein. The host 20 cells are cultured under conditions whereby the nucleic acid sequence coding for the particular protein is expressed. After a suitable amount of time for the protein to accumulate, the protein is purified from the host cells or medium surrounding the cells.

25 A human gene coding for  $\alpha$ -1-antichymotrypsin can be readily obtained from a human liver cDNA library. Suitable libraries can be obtained from commercial sources such as Clontech, Palo Alto, CA. Positive clones are then subjected to DNA sequencing to determine the presence of a 30 DNA sequence coding for  $\alpha$ -1-antichymotrypsin. DNA sequencing is readily accomplished using the chain termination method of Sanger et al., *Proc. Nat'l. Acad. Sci., U.S.A.*, 1977, 74, 5463.

35 The DNA sequence coding for  $\alpha$ -1-antichymotrypsin may then be manipulated using the polymerase chain reaction, PCR, or alternatively, inserted into a cassette vector, as disclosed in U.S. Patent 5,079,336, the

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disclosures of which is hereby incorporated by reference.

Expression vectors, host cells and cell cultures suitable for use in the invention are chosen from expression systems capable of synthesizing  $\alpha$ -1-5 antichymotrypsin analogue products. Host cells suitable for use in the invention include prokaryotic and eukaryotic cells that can be transformed to stably contain and express  $\alpha$ -1-antichymotrypsin, as disclosed in U.S. Patent 5,079,336, incorporated herein by reference. Suitable 10 types of cells for practicing the present invention include bacterial, yeast and mammalian cells.

Nucleic acids coding for recombinant  $\alpha$ -1-antichymotrypsin may be expressed in prokaryotic or eukaryotic host cells, including the most commonly used 15 bacterial host cell for the production of recombinant proteins, *E. coli*. Other microbial strains may also be used, such as *Bacillus subtilis* and other enterobacteriaceae such as *Salmonella typhimurium* or *Serratia marcescens*, various species of *Pseudomonas* or 20 other bacterial strains.

Commonly used eukaryotic systems include yeast, such as *Saccharomyces cerevisiae*, insect cells such as *Spodoptera frugiperda*, chicken cells such as E3C/O and SL-29, mammalian cells such as HeLa, Chinese hamster ovary 25 cells (CHO), COS-7 or MDCK cells, and the like. The foregoing list is illustrative only and is not intended in any way to limit the types of host cells suitable for expression of the nucleic acid sequences of the invention.

As used herein, expression vectors refer to any 30 type of vector that can be manipulated to contain a nucleic acid sequence coding for recombinant  $\alpha$ -1-antichymotrypsin, such as plasmid expression vectors and viral vectors. The selection of the expression vector is based on compatibility with the desired host cell such that 35 expression of the nucleic acid coding for recombinant  $\alpha$ -1-antichymotrypsin results. Plasmid expression vectors comprise a nucleic acid sequence of the invention operably

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linked with at least one expression control element such as a promoter. In general, plasmid vectors contain replicon and control sequences derived from species compatible with the host cell. To facilitate selection of plasmids 5 containing nucleic acid sequences of the invention, plasmid vectors may also contain a selectable marker such as a gene coding for antibiotic resistance. Suitable examples include, and are not limited to, the genes coding for ampicillin, tetracycline, chloramphenicol or kanamycin 10 resistance.

Suitable expression vectors, promoters, enhancers and other expression control elements are known in the art and may be found in Sambrook et al., *Molecular Cloning: A Laboratory Manual*, second edition, Cold Spring Harbor 15 Laboratory Press, Cold Spring Harbor, NY (1989). The plasmids and vectors set forth below are examples only and are not meant to be limiting in any way. Plasmids such as pBR322, pUC18, pUC19, pZMS, and pZM may be used for expression in *E. coli*. Plasmid YRp7 may be used for 20 expression in *S. cerevisiae*. Plasmids such as pMT2 and pMSG may be used for expression in mammals. Suitable viral vectors include baculovirus, *Vaccinia* virus and adenovirus.

The particulars for the construction of expression systems suitable for desired hosts are known to 25 those in the art. For recombinant production of the protein, the DNA encoding it is suitably ligated into the expression system of choice and the system is then transformed into the compatible host cell which is then cultured and maintained under conditions wherein expression 30 of the foreign gene takes place. The peptide of this invention is then recovered from the culture, either by lysing the cells or from the culture medium as appropriate and known to those in the art.

Specifically, the expression vector comprising 35 the nucleic acid sequence coding for human  $\alpha$ -1-antichymotrypsin preferably further comprises transcription and translation control elements operatively linked to the

nucleic acid sequence coding for human  $\alpha$ -1-antichymotrypsin. For example, in an upstream position may be a promoter followed by a translation initiation signal comprising a ribosome binding site and an initiation codon, 5 and in a downstream position may be a transcription termination signal. The transcription and translation control elements may be ligated in any functional combination or order. The transcription and translation control elements used in any particular embodiment of the 10 invention will be chosen with reference to the type of cell into which the expression vector will be introduced, so that an expression system is created.

It is preferable to use a strong promoter, such as the *E. coli* trp-lac promoter or the T7 pL promoter, to 15 ensure high levels of expression of the protein product. The p1Nomp and  $\beta$ -lactamase promoters have been found to give low or no yields of  $\alpha$ -1-antichymotrypsin when operatively linked with DNA coding for  $\alpha$ -1-antichymotrypsin. It is also preferable that the promoter 20 is an inducible promoter, such as  $P_L$  promoter, to avoid possible host cell toxicity during accumulation of the product.

Alternatively, a gene expression system based on bacteriophage T7 RNA polymerase as disclosed in Studier and 25 Moffatt, *J. Mol. Biol.*, 1986, 189, 113, which is specifically incorporated as if fully set forth herein, may be used. In this system, *E. coli* cells transformed with plasmids containing the bacteriophage T7 promoter operatively linked with a DNA sequence coding for a 30 selected product are infected with lambda phage having an expressible gene for T7 RNA polymerase. The cells are infected with phage after sufficient copies of the plasmids are present in the host cells and protein synthesis begins soon after infection.

35 Transformed host cells containing a DNA sequence coding for human  $\alpha$ -1-antichymotrypsin analogues may then be grown in an appropriate medium for the host. Where an

inducible promoter is employed, the host cell may be grown to high density and the promoter turned on for expression of the fusion protein and protease. Where the promoter is not inducible, then constitutive production of the protein 5 product will occur. Constitutive production of the  $\alpha$ -1-antichymotrypsin analogue is preferable in expressions systems where it is not substantially toxic to the host cell. The cells may be grown until there is no further increase in analogue formation or the ratio of nutrient 10 consumption to analogue formation falls below a predetermined level, at which time the cells may be harvested, lysed and the protein product obtained and substantially purified in accordance with conventional techniques. Such techniques include chromatography, 15 electrophoresis, extraction, and density gradient centrifugation.

As used herein, host cells transformed with an appropriate expression vector, and cell cultures of such host cells may be used to synthesize  $\alpha$ -1-antichymotrypsin 20 of the present invention. Protein preparations of recombinant analogues of  $\alpha$ -1-antichymotrypsin may also be prepared from host cells and cell cultures.

Host cells are cultured in medium appropriate to maintain the cells and produce a mixture of cells and 25 medium containing recombinant  $\alpha$ -1-antichymotrypsin analogues. Alternatively, the mixture may be purified such that recombinant  $\alpha$ -1-antichymotrypsin is purified therefrom.

Purification methods useful herein include, but 30 are not limited to, ion exchange chromatography, affinity chromatography, electrophoresis, dialysis and other methods of protein purification known in the art. Protein preparations, of purified or unpurified recombinant  $\alpha$ -1-antichymotrypsin analogue produced by host cells, are 35 produced which comprise  $\alpha$ -1-antichymotrypsin and perhaps other material from the mixture of cells and medium, depending on the degree of purification of the protein.

Thus, the present invention provides a method of producing human  $\alpha$ -1-antichymotrypsin or analogue comprising culturing a host cell capable of expressing human  $\alpha$ -1-antichymotrypsin or analogue to produce cells containing 5 human  $\alpha$ -1-antichymotrypsin or analogue and optionally purifying the mixture to produce human  $\alpha$ -1-antichymotrypsin or analogue in a purified form.

10 Protein preparations, of purified or unpurified recombinant  $\alpha$ -1-antichymotrypsin analogue produced by host 15 cells, are accordingly produced which comprise  $\alpha$ -1-antichymotrypsin and other material such as host cell components and/or cell medium, depending on the degree of purification of the protein.

20 The term "purified", when used to describe the state of nucleic acid sequences of the invention, refers to 25 nucleic acid sequences substantially free of nucleic acid not coding for human  $\alpha$ -1-antichymotrypsin or other materials normally associated with nucleic acid in non-recombinant cells, i.e., in its "native state".

25 The term "purified" or "in purified form" when used to describe the state of  $\alpha$ -1-antichymotrypsin protein or analogue protein, refers to  $\alpha$ -1-antichymotrypsin or analogue free, to at least some degree, of cellular material or other material normally associated with it in 30 its native state. Preferably  $\alpha$ -1-antichymotrypsin or analogue has a purity (homogeneity) of at least about 25% to about 100%. More preferably the purity is at least about 50%.

35 The analogues of  $\alpha$ -1-antichymotrypsin of the present invention exhibit antichymotrypsin activity and are useful in the same manner as native or wild-type  $\alpha$ -1-antichymotrypsin. The analogues are useful as chymase inhibitors, and in the treatment and prevention of blood clots, reperfusion injury, and inflammation of the lungs. In the case of lung inflammation, inflammation may be caused by aspiration of an acidic substance such as and not limited to stomach contents, smoke, infection, such as

pathogen infection including infection from a gram negative bacterium (*Escherichia* and *Pseudomonas*, for example).

The analogues of the invention may be administered with a pharmaceutically-acceptable carrier or 5 diluent, such as a saline solution or other buffer. Suitable pharmaceutical carriers are well known in the art and are described for example, in Gennaro, Alfonso, ed., Remington's Pharmaceutical Sciences, 18th Edition, 1990, Mack Publishing Co., Easton PA, a standard reference text 10 in this field. Carriers may be selected with regard to the intended route of administration and the standard pharmaceutical practice. Dosages will be set with regard to weight, and clinical condition of the patient. The proportional ratio of active ingredient to carrier will 15 naturally depend on the chemical nature, solubility, and stability of the analogues, as well as the dosage contemplated.

The analogues of the invention may be employed in the method of the invention singly or in combination with 20 other compounds, including and not limited to other analogues of the invention. The method of the invention may also be used in conjunction with other treatments including and not limited to antibodies, toxins, and antisense oligonucleotides. For *in vivo* applications the 25 amount to be administered will also depend on such factors as the age, weight, and clinical condition of the patient. The analogues of the present invention may be administered by any suitable route, including inoculation and injection, for example, intravenous, oral, intraperitoneal, 30 intramuscular, subcutaneous, topically, and by absorption through epithelial or mucocutaneous linings, for example, nasal, oral, vaginal, rectal and gastrointestinal.

The mode of administration of the analogues, medicaments, and compositions of the present invention, may 35 determine the sites in the organism to which the analogue may be delivered. For instance, topical application may be administered in creams, ointments, gels, oils, emulsions,

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5 pastes, lotions, and the like. For parenteral administration, the analogues may be used in the form of a sterile aqueous solution which may contain other solute, for example, sufficient salts, glucose or dextrose to make  
10 the solution isotonic. For oral mode of administration, the present invention may be used in the form of tablets, capsules, lozenges, troches, powders, syrups, elixirs, aqueous solutions and suspension, and the like. Various disintegrants such as starch, and lubricating agents may be  
15 used. For oral administration in capsule form, useful diluents are lactose and high molecular weight polyethylene glycols. When aqueous suspensions are required for oral use, certain sweetening and/or flavoring agents may be added.

15 Methods of inhibiting chymase, treating skin inflammation, treating and preventing blood clotting, treating lung inflammation, and treating reperfusion injury are also provided whereby an  $\alpha$ -1-antichymotrypsin analogue having amino acid substitutions at position 358, or  
20 positions 356-361 with position 358 selected from the amino acids identified above; or wherein the amino acids of human wild type  $\alpha$ -1-antichymotrypsin Thr-Leu-Leu-Ser-Ala-Leu corresponding to positions 356 - 361 are substituted with Ile-Pro-Xxx-Ser-Ile-Pro; is added to a sample exhibiting  
25 the condition to be treated.

For purposes of the current invention, animals include but are not limited to the Order Rodentia, such as mice and the Order Logomorpha, such as rabbits; more particularly the Order Carnivora, including Felines (cats)  
30 and Canines (dogs); even more particularly the Order Artiodactyla, Bovines (cows) and Suines (pigs) and the Order Perissodactyla, including Equines (horses); and most particularly the Order Primates, Ceboids and Simoids (monkeys) and Anthropoids (humans and apes). The animals  
35 of the most preferred embodiments are humans.

**EXAMPLES****PRODUCTION AND PURIFICATION OF RECOMBINANT  $\alpha$ -1-ANTICHYMO TRYPSIN ANALOGUES****Materials**

5 Chymotrypsin was obtained from Sigma or Boehringer-Mannheim. All chromophoric protease substrates were obtained from Bachem, as was phenylmethylsulfonyl fluoride (PMSF).

Human serum  $\alpha$ -1-antichymotrypsin was prepared 10 using a procedure based on the work of Tsuda et al., Tokai, *J. Exp. Clin. Med.*, 1982, 7, 201. This method affords pure  $\alpha$ -1-antichymotrypsin in three steps, batchwise elution from DNA cellulose, G-150 chromatography and KCl gradient elution from DNA cellulose.

15 Plasmid constructions and DNA manipulations were carried out following Sambrook et al., *Molecular Cloning: A Laboratory Manual*, second edition, Cold Spring Harbor Laboratory Press, Cold Spring Harbor, NY (1989).

20 **Identification and Sequencing of the Gene from Human Antichymotrypsin**

A human liver cDNA library in the phage expression vector lambda-gt11 provided by Mitchell Weiss, Department of Human Genetics, University of Pennsylvania, was screened according to the method of Young and Davis, 25 *Proc. Natl. Acad. Sci., U.S.A.*, 1977, 74, 5463, with polyclonal antisera raised against C1 esterase inhibitor (DAKO, Santa Barbara, CA), a related serine protease inhibitor. Positives clones were picked, rescreened and plaque-purified. DNA sequencing was performed with the 30 chain termination method of Sanger et al., *Proc. Natl. Acad. Sci.*, 1977, 74, 5463, using oligonucleotide primers obtained from the Nucleic Acid Synthesis Center of the Wistar Institute (Philadelphia, PA).

The DNA sequence and the derived amino acid 35 sequence of the EcoR1 fragment from one of the positive lambda-gt11 cDNA clones contained the entire coding region of the mature human  $\alpha$ -1-antichymotrypsin, as depicted in

Figure 1. The construct also included a 21 nucleotide extension of the 5'-end encoding 7 amino acids, comprising the sequence 5'-Met-Ala-Ser-Leu-Cys-His-Pro- (SEQ ID NO: 5). The mature protein contains 398 amino acids ( $M_r$  45,031) 5 starting from amino acid position 1, Asn, at the amino terminus and contains a single cysteine residue at position 236.

**Preparation of Recombinant  $\alpha$ -1-Antichymotrypsin and Analogues Having Tryptophan at Amino Acid Position 358**

10 The nucleic acid sequence coding for human  $\alpha$ -1-antichymotrypsin may be obtained as described above and subcloned into pUC19 (Promega, Madison, Wis.) as set forth in U.S. Patent 5,079,336, incorporated herein by reference. In the present example, however, the analogue of  $\alpha$ -1- 15 antichymotrypsin having the substitution of tryptophan for leucine at position 358, rACT-L358W, was prepared according to PCR as follows.

20 The commercially available plasmid pKC30 was cut by BamHI, the single strand created staggered ends which were filled by Klenow reaction. The linearized plasmid with both ends blunt ended was self ligated, and *E. coli* N4830-1 was transformed by the ligation reaction mixture. The plasmid purified from transformants was pKC30(-BamHI), 25 indicating pKC30 with the only BamHI site removed. This pKC30(-BamHI) was digested by HpaI, and created two blunt ends for the next ligation step.

30 A 0.2 kb fragment containing a ribosome binding site was cut out of the following set of plasmids: pAR 3038, pAR3039, and pAR3040, by XbaI and EcoRV. The EcoRV cut created a blunt end. The staggered end created by XbaI was filled by the Klenow reaction. With both ends blunted, the three 0.2 kb fragments were separately ligated to HpaI digested pKC30(-BamHI). The three ligation mixtures were used to transform N4830-1 separately. Three vectors were 35 obtained from these transformants. They were named pZM3038, pZM3039, and pZM3040, corresponding to three reading frames. These pZM vectors contained a pL promoter

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from pKC30, and received Shine-Dalgarno sequences from pAR vectors. The unique cloning site of these vectors is BamHI which is located in the fragment from pAR.

One of pZM3038, pZM3039, or pZM3040 was cut by 5 NheI, and produced two fragments, about 5.9 kb, and about 0.75 kb. The 5.9 kb fragment was gel purified and ligated to recircularize. N4830-1 was transformed with this, 10 ligation reaction. The plasmid isolated from the transformants was named pZMs. pZMs has a unique cloning site - NheI which is downstream from the pL promoter, Shine-Dalgarno sequence, and the start codon.

Primers 1, 2, 3, and 4, as shown in Table 1, were prepared by standard techniques set forth in Sambrook et al., *Molecular Cloning: A Laboratory Manual*, second 15 edition, Cold Spring Harbor Laboratory Press, Cold Spring Harbor, NY (1989) and used in a polymerase chain reaction (PCR) protocol to introduce bases coding for tryptophan into the sequence coding for  $\alpha$ -1-antichymotrypsin. Standard PCR protocols are known to those skilled in the 20 art.

Table 1

Primer	Sequence	SEQ ID NO:
1	5' - <u>CCCCATATGGCTAGCAACAGCCC</u> ACTTG-3'	1
2	5' -TAATGCAGACCAGAGGGTGA-3'	2
25 3	5' -ATCACCCCTCTGGTCTGCATTA-3'	3
4	5' -TTTCATAT <u>GGCTAGCGCTCTAGGCTTGC</u> -3'	4

The full-length nucleotide sequence was created in two parts, Fragments A and B, which were combined to 30 produce the full-length nucleotide sequence.

To construct Fragment A, two primers were used. Primer 1 contains the 5' sequence of the coding or sense strand for  $\alpha$ -1-antichymotrypsin with an extended 5' tail which contains an NheI cloning site, which is shown 35 underlined in Table 1. Primer 2 comprises a 3' tail having bases coding for tryptophan to replace the bases coding for

leucine at position 358 (the tryptophan codon is shown in bold letters in Table 1). Primers 1 and 2 were then used with the polymerase chain reaction and the sequence coding for  $\alpha$ -1-antichymotrypsin subcloned in pUC19 to produce

5 Fragment A that codes for the N-terminus through position 358.

Standard PCR methods were followed for the production of Fragment A. 1  $\mu$ l of 100 ng/ $\mu$ l of Primer 1 and 1  $\mu$ l of 100 ng/ $\mu$ l of Primer 2, 10  $\mu$ l of 10x PCR buffer, 10 10  $\mu$ l of 2mM dNTP and 0.5  $\mu$ l of Taq enzyme were added to 10 ng of template DNA, pUC19 containing the  $\alpha$ -1-antichymotrypsin gene, with distilled water bringing the reaction volume to 100  $\mu$ l. Three steps of PCR were performed, 94°C for 15 seconds, 52°C for 15 seconds, and 15 72°C for 1 second. The three steps equal one cycle, thirty cycles were run.

To construct Fragment B, two different primers were used. Primer 3 contains nucleotides of the coding or sense strand comprising a 3' tail having bases coding for 20 tryptophan to replace the bases coding for leucine at position 358 (the tryptophan codon is shown in bold letters in Table 1). Primer 4 has an extended 5' tail that contains an NheI cloning site, which is shown underlined in Table 1. Primers 3 and 4 were then used with the 25 polymerase chain reaction and the sequence coding for  $\alpha$ -1-antichymotrypsin subcloned in pUC19 to produce fragment B that codes for position 358 through the C-terminus. The PCR protocol set forth above for the production of Fragment A was also followed for the production of Fragment B.

30 The full-length sequence was then produced by the protocol set forth above for Fragment A, with 5-10 ng of each of Fragment A and Fragment B. The fragments were denatured and reannealed. The fragments were reannealed to produce heteroduplexes of Fragments A and B overlapping at 35 a sequence coding for tryptophan that was created via Primers 2 and 3. The heteroduplexes of Fragments A and B were extended using Tag DNA polymerase with the overlapping

portions of Fragments A and B serving as primers to produce the full-length sequence coding for  $\alpha$ -1-antichymotrypsin having tryptophan substituted for leucine at position 358 of the wild-type. The full-length sequences were then 5 amplified using Primers 1 and 4.

The amplified full-length sequence was then digested with NheI and inserted into the expression vector pZMs, which was digested with NheI. *E. coli* was then transformed with pZMs containing the full length gene. As 10 such, analogues of  $\alpha$ -1-antichymotrypsin with an altered amino acid position 358 of the reactive site were expressed. Thus, leucine at amino acid position 358 was changed to tryptophan. This analogue is represented herein 15 as rACT-L358W. Other analogues of human wild type  $\alpha$ -1-antichymotrypsin of the present invention may be similarly prepared.

**Preparation of Recombinant  $\alpha$ -1-Antichymotrypsin Having Met-Ala-Ser or Ala-Ser N-Terminal Extension**

Stable monomers were expressed directly by 20 eliminating the N-terminal cysteine residue through deletion of the nucleotides encoding the Leu-Cys-His-Pro (SEQ ID NO: 6) sequence within the N-terminal sequence Met-Ala-Ser-Leu-Cys-His-Pro (SEQ ID NO: 5) encoded within the nucleotide sequence of wild type  $\alpha$ -1-antichymotrypsin to 25 produce the nucleotide sequence encoding rMAS-ACT. As such, the amino acids leucine, cysteine, histidine and proline at amino acid positions -4 to -1 of wild type  $\alpha$ -1-antichymotrypsin were deleted. The N-terminal extension becomes methionine-alanine-serine at amino acid positions 30 -3 to -1. Such extension was accomplished by PCR amplification, set forth above, of the entire coding sequence with an N-terminal primer 5' -CCCATATGGCTAGAACAGCCCCACTTG-3' (SEQ ID NO: 1). The C-terminal primer was 5'-TTTCATATGGCTAGCGCTTAGGCTTGC-3' (SEQ 35 ID NO: 4) in which the underlined sequence GCTAGC served as the insertion site. The underlined CTA sequence creates a TAG termination codon in the sense strand of the vector.

The sequence was cloned into pZMs. The amplified full-length sequence was digested with NheI and inserted into the expression vector pZMs, which was digested with Nhe I. *E. coli* was then transformed with pZMs containing the gene 5 with the altered N-terminal extension. As such, analogues of  $\alpha$ -1-antichymotrypsin were produced by altering amino acid positions -4 to -1, such that the amino acids leucine, cysteine, histidine and proline were deleted. This analogue is represented herein as rMAS-ACT.

10 **Expression of rACT Analogues**

*E. coli* N4830-1 was transformed with the expression vectors pACT-L358W, pMAS-ACT, pAS-ACT, pMAS-ACT-L358W or pAS-ACT-L358W by standard calcium chloride methods as described by Sambrook et al., *Molecular Cloning: A 15 Laboratory Manual*, second edition, Cold Spring Harbor Laboratory Press, Cold Spring Harbor, NY (1989).

**Small scale growth conditions and extraction**

Fresh overnight cultures of *E. coli* strain N4830-1 transformed with the aforementioned expression vectors 20 were diluted to 1.5% in LB broth containing ampicillin (Na<sup>+</sup> salt, 0.1 mg/ml) and grown at 30°C in a shaking incubator to an  $A_{600\text{nm}}$  of 0.18, induced by raising the temperature to 42°C and grown for an additional five to eight hours. The cells were centrifuged and disrupted in a French press.

25 **Purification and Characterization of Recombinant  $\alpha$ -1-Antichymotrypsin Analogues**  
**Large-Scale Growth of *E. coli***

*E. coli* strain N4830-1 transformed with the aforementioned expression vectors were grown in LB media 30 containing ampicillin (Na<sup>+</sup> salt, 0.1 m/ml) at 30°C to an  $A_{600\text{nm}}$  of 0.18 in a 15 L carboy fitted with an oxygen bubbler. The cells were induced by raising the temperature to 42°C and grown for an additional six hours to a final  $A_{600\text{nm}}$  of approximately 0.9 - 1.0.

**Extraction and column chromatography**

All purification steps were carried out at 4°C. In a typical preparation of  $\alpha$ -1-antichymotrypsin analogue, cell paste was dispersed in 10 mM potassium phosphate buffer, pH 6.9 (25 ml) and lysed by three passes through a French press at 10,000 psi and 4°C. Cell debris was removed by centrifugation at 30,000  $\times$  g for 30 minutes at 4°C. Supernatant (25 ml) was loaded onto a column (4.9 cm<sup>2</sup>  $\times$  37 cm) of Sepharose Fast Q (Pharmacia) that had been equilibrated to 50 mM Tris-Cl, pH 7.5, containing 50 mM KCl. Protein eluted with a linear gradient of KCl in 50 mM Tris-Cl, pH 7.5 (50-500 mM in 2 L). Fractions (15 ml) were monitored for protein by  $A_{280nm}$  and assayed for antichymotrypsin activity as described herein. Analogue eluted at approximately 200 mM KCl. Fractions containing analogue were combined and dialyzed against two volumes (2.5 L each) of 10 mM potassium phosphate buffer, pH 6.9 over 48 hours. The dialyzed solution was then applied to a DNA-cellulose column (1.7 cm<sup>2</sup>  $\times$  20 cm) that had been pre-equilibrated with 10 mM potassium phosphate, pH 6.9, containing 10 mM KCl. After loading, the column was first washed with the same buffer (20 ml). The column was eluted with a linear gradient of KCl (10-500 mM, 300 ml) in the same buffer. Fractions (8 ml) were assayed for protein and antichymotrypsin activity as described herein. Analogue eluted at approximately 350 mM KCl. Fractions containing antichymotrypsin activity were analyzed for purity by SDS-PAGE, performed according to Laemmli, *Nature* (London) 1970, 227, 680. Each portion was concentrated by ultrafiltration using Amicon YM-10 membranes and dialyzed overnight against 50 mM Tris-Cl, pH 7.5 (500 ml). In some cases recombinant protein was further purified on an FPLC Mono Q anion exchange column, using the conditions described above.

**Antichymotrypsin Activity Assays**

Antichymotrypsin activity could not be directly measured in crude bacterial lysates because of large

background inhibitory activity in the lysate itself. The background activity was separated from the antichymotrypsin by anion exchange chromatography using a Mono Q HR5/5 anion exchange FPLC column (Pharmacia) fitted into a pump (LKB 2150 pump), a 2152 gradient controller and a UV absorbance detector (Waters 440 UV absorbance detector) with an extended wavelength module. Chromatography was typically conducted on the extract from 200 mg of cells. The separation involved an isocratic wash (5 minutes) with 50 mM Tris-Cl buffer, pH 7.5, containing 50 mM KCl, followed by a linear gradient of KCl (50-350 mM in 30 minutes) at a flow rate of 1.0 ml/minute. Protein absorbance was monitored at both 214 and 280 nm. Fractions (1.0 ml) were collected and assayed for antichymotrypsin or antitrypsin activity measured as the inhibition of the chymotrypsin-catalyzed hydrolysis of substrate N-suc-Ala-Ala-Pro-Phe-p-nitroanilide (0.1 ml of 10 mM solution in 90% DMSO), DelMar et al., *Anal. Biochem.*, 1979, 99, 316 or of trypsin-catalyzed hydrolysis of substrate N-Bzl-Pro-Phe-Arg-p-nitroanilide (0.02 ml of a 14.6 mM solution in 90% DMSO). A typical chymotrypsin assay contained in (1.0 ml): 100 mM Tris-Cl buffer, pH 8.3, 0.005% (v/v) Triton X-100, bovine pancreatic chymotrypsin (18 mmol) and column eluate (0.005 - 0.5 ml). The assay mixture was pre-incubated at room temperature for 5 minutes, substrate (0.01 ml of a 10 mM solution in 90% DMSO) was added, and remaining chymotrypsin activity was determined by the rate of change in  $A_{410\text{nm}}$  caused by the release of p-nitroaniline. A typical trypsin assay contained (in 1.0 ml): 100 mM Tris-Cl buffer, pH 8.3, 0.005% (v/v) Triton X-100, bovine trypsin (8.6 pmol) and sample (0.005 - 0.5 ml). The assay mixture was preincubated at room temperature for 10 minutes before substrate (0.02 ml of a 15 mM solution in 90% DMSO) was added and remaining trypsin activity was determined as above. Measurements of optical absorbance were conducted at 25°C using a spectrophotometer (Hewlett Packard 8452A) fitted with a temperature controlled sample compartment.

**INTERACTION OF RECOMBINANT  $\alpha$ -1-ANTICHYMO TRYPSIN AND ANALOGUES WITH HUMAN CHYMASE**

**Materials**

Peptide-nitroanilide substrates were purchased  
5 from Sigma or Bachem. TSK-Heparin-5PW HPLC column was purchased from Supelco. Heparin-Sepharose was from Pharmacia. Immobilon-P (PVDF membranes) was purchased from Millipore.

The analogue of antichymotrypsin wherein the  
10 leucine at position 358 of wild-type is substituted with tryptophan (W) was produced as described herein.

**Purification of Human Chymase**

Mast cell proteinases were extracted from human skin and fractionated on a 500 ml heparin-Sepharose column.  
15 Chymase, eluted from heparin-Sepharose in single step with 2 M NaCl, 0.1 M MOPS (pH 6.8) was further purified by affinity chromatography using soybean trypsin inhibitor (SBTI)-Sepharose. The fraction of chymase binding to heparin-Sepharose was variable. In extracts resulting in  
20 an enzyme heparin-Sepharose binding of 30-70%, an alternate purification method was used. Chymase in the flow-through was precipitated by addition of protamine chloride. After solubilization of the precipitate in high salt buffer, chymase was absorbed to a phenylbutylamine-Sepharose column  
25 (20 ml resin) and chymase was eluted in a single step by addition of 0.4 M NaCl, 0.01 M [3-(N-morpholino)-propane-sulfonic acid], MOPS, (pH 6.8), 0.2 M D tryptophan methyl ester, D-Trp-OMe, solution. The proteinase was then applied to a heparin-Sepharose column where it absorbed to  
30 the column and was eluted with a salt gradient.

Chymase purified by both procedures had identical catalytic properties, migrated identically on SDS gels, and had the same stoichiometry of inhibition when titrated against serum ACT. Enzyme purified by both procedures was  
35 used in these studies.

**Determination of Inhibitor and Proteinase Concentrations**

Concentrations of  $\alpha$ -1-recombinant antichymotrypsins were determined by titration with chymotrypsin. Titrations were performed in 50  $\mu$ l (25°C) containing 0.1 M Tris-HCl, 0.5 M NaCl, 0.01% Triton X-100 and 150-300  $\mu$ M proteinase. Residual activity was determined after 10-15 minute incubations by diluting sample with 1 ml assay buffer containing the substrates SucAAPF-pNA or CBZ-GPA-pNA (carbobenzoxy-Gly-Pro-Arg p-nitroanilide) at 1 mM. Stock chymotrypsin solution was standardized with the active site titrants N-trans-cinnamoylimidazole. Chymase concentrations were determined using its specific activity 2.7  $\mu$ mol of product min-1/nmol chymase measured under standard assay conditions containing 1 mM of substrate SucAAPF-pNA;  $\epsilon_{410} = 8800$  (the extinction coefficient of p-nitroaniline) was used to quantify released p-nitroaniline.

#### Chymase Assay

Reactions of chymase with recombinant  $\alpha$ -1-antichymotrypsin and analogues were performed at 25°C in 50-150  $\mu$ l of a solution containing 0.2 M Tris-HCl (pH 8.0), 1M NaCl, 0.01% Triton X-100 and 150-400 nM chymase. After incubation with inhibitor, independently including the aforementioned analogues, for appropriate times, residual activity was measured by dilution of a sample aliquot in 1 ml assay buffer containing 1 mM substrate as described above. The reactions of chymase with inhibitor were stopped by the addition of a general serine proteinase inhibitor (PMSF) and a sample of the reaction mixture was electrophoresed to determine reaction products.

#### Reaction of Chymase with Variant rACTs

Stoichiometry of inhibition (SI) values and second order rate constants were determined for the analogues. Titrations (pH 8.0, 1 M NaCl, 25°C) to obtain the SI for each recombinant  $\alpha$ -1-antichymotrypsin are presented in Figure 2. Residual activities in these

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studies were achieved within minutes and remained constant for at least 24 hours. Second order rate constants ( $k_{obs/I}$ ) were evaluated for all rACTS at  $(rACT)_0/(chymase)_0 \gg 1$ . The reaction of chymase with serum  $\alpha$ -1-antichymotrypsin, 5 reactions appears pseudo first order when  $(I)_0/(E)_0$  ratios are approximately 10 fold higher than the SI. Reaction conditions in rate studies were similar to titrations, measurements were made at NaCl concentrations of 1 M and 2 M.

#### 10 Inhibition Rate Constants

Progress curves were determined under pseudo-first order conditions  $((I)_0 \gg (E)_0)$  in the presence of substrate. Reactions contained 0.25 to 1.0 mM SucAAPF-pNA, 2-2.5 nM chymase and inhibitor. Absorbance 15 was continually monitored for 15 minutes, and instantaneous velocities were determined over 1 minute intervals by regression analysis. Plots of the instantaneous velocity vs time (t) were fit by non-linear methods to the expression  $Ae^{-k't}$  to determine  $k'$ , the apparent first order 20 rate constant; (A) is the initial activity.  $k_{obs/I}$  was calculated from the relationship,  $k_{obs/I} = k'((S/Km)+1)/I$ , where S is the initial substrate concentration, Km is the Michaelis constant for chymase hydrolysis of the substrate under the experimental conditions, and I is the initial 25 inhibitor concentration. Reactions were monitored for at least three half-lives. Km was 0.80 mM in 1.0 M NaCl and 0.49 in 2.0 M NaCl.

Rate constants and SI for all variants are collected in Table 2. Only minor changes in values were 30 observed at the two different NaCl concentrations. The results illustrate the importance of the P1 residue, change of Leu to Trp, in modulating the SI and rate of inhibition. The reaction of chymase with serum ACT has a stoichiometry 35 of inhibition (SI) of 4.0 due to generation of degraded inhibitor (3.5 moles degraded inhibitor/mole chymase) in a reaction competing with chymase inhibition.

Table 2

Kinetic Parameters for the Reaction of Human Chymase with Recombinant  $\alpha$ -1-Antichymotrypsin and Analogues

	rACT variant	NaCl (M)	$k_{obs}/[I]^a$ (M $^{-1}$ s $^{-1}$ )	SI
	Leu358W	1	151,000	1.5
	Leu358W	2	280,000	1.2
	Leu358	1	27,000	4.0
10	Leu358	2	42,500	3.5
	Leu358 (Cas)	1	60,000	2.0

a - experimental conditions for measurement rate constants were similar to those of titrations except for presence of substrate and 9% Me<sub>2</sub>SO<sub>4</sub>. Most  $k_{obs}/[I]$  values are the average of two experiments and deviation from the average was typically less than 15%.  $K_{obs}/[I]$  values for rACT-L358 in 2 M NaCl and rACT-L258W in 1 M NaCl were based on 4 and 5 measurements, respectively; SD were 8% and 15% of the reported values respectively. Leu358(Cas) refers to the cassette version of the analogue prepared according to the methods set forth in U.S. Patent 5,079,336.

Various modifications of the invention in addition to those shown and described herein will be apparent to those skilled in the art from the foregoing description. Such modifications are also intended to fall within the scope of the appended claims.

## SEQUENCE LISTING

## (1) GENERAL INFORMATION:

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(ii) TITLE OF INVENTION:  $\alpha$ -1-Antichymotrypsin Having Chymase Inhibiting Activity

(iii) NUMBER OF SEQUENCES: 8

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(B) COMPUTER: IBM PS/2

(C) OPERATING SYSTEM: PC-DOS

(D) SOFTWARE: WORDPERFECT 5.1

## (vi) CURRENT APPLICATION DATA:

(A) APPLICATION NUMBER:

(B) FILING DATE: Herewith

(C) CLASSIFICATION:

## (vii) PRIOR APPLICATION DATA:

(A) APPLICATION NUMBER:

(B) FILING DATE:

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(2) INFORMATION FOR SEQ ID NO: 1:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 28 base pairs  
(B) TYPE: nucleic acid  
(C) STRANDEDNESS: single  
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 1:

CCCCATATGG CTAGAACAG CCCACTTG

(3) INFORMATION FOR SEQ ID NO: 2:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 20 base pairs  
(B) TYPE: nucleic acid  
(C) STRANDEDNESS: single  
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 2:

TAATGCAGAC CAGAGGGTGA

(4) INFORMATION FOR SEQ ID NO: 3:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 21 base pairs  
(B) TYPE: nucleic acid  
(C) STRANDEDNESS: single  
(D) TOPOLOGY: linear

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(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 3:

ATCACCCCTCT GGTCTGCATT A

(5) INFORMATION FOR SEQ ID NO: 4:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 28 base pairs

(B) TYPE: nucleic acid

(C) STRANDEDNESS: single

(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 4:

TTTCATATGG CTAGCGCTCT AGGCTTGC

(6) INFORMATION FOR SEQ ID NO: 5:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 7 amino acids

(B) TYPE: protein

(C) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 5:

Met-Ala-Ser-Leu-Cys-His-Pro

(7) INFORMATION FOR SEQ ID NO: 6:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 4 amino acids

(B) TYPE: protein

(C) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 6:

Leu-Cys-His-Pro

## (8) INFORMATION FOR SEQ ID NO: 7:

## (i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 6 amino acids

(B) TYPE: protein

(C) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 7:

Thr-Leu-Leu-Ser-Ala-Leu

## (9) INFORMATION FOR SEQ ID NO: 8:

## (i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 6 amino acids

(B) TYPE: protein

(C) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 8:

Ile-Pro-Xxx-Ser-Ile-Pro

## WHAT IS CLAIMED:

1. An analogue of human wild type  $\alpha$ -1-antichymotrypsin wherein the amino acid corresponding to the leucine at amino acid position 358 of wild-type  $\alpha$ -1-antichymotrypsin is substituted with an amino acid selected from the group consisting of tryptophan, alanine, asparagine, aspartic acid, cysteine, glutamine, glutamic acid, glycine, histidine, isoleucine, lysine, methionine, phenylalanine, proline, serine, threonine, tyrosine, and valine.
2. An analogue of human wild type  $\alpha$ -1-antichymotrypsin wherein the amino acids corresponding to the amino acids Thr-Leu-Leu-Ser-Ala-Leu at positions 356 to 361 of wild-type  $\alpha$ -1-antichymotrypsin are substituted with amino acids Ile-Pro-Xxx-Ser-Ile-Pro, wherein Xxx is selected from the group consisting of methionine, tryptophan, alanine, asparagine, aspartic acid, cysteine, glutamine, glutamic acid, glycine, histidine, isoleucine, lysine, phenylalanine, proline, serine, threonine, tyrosine, and valine.
3. An analogue of claim 2 wherein the amino acid at Xxx is methionine.
4. An analogue of claims 1, 2, or 3 having chymase inhibiting activity.
5. An analogue of claim 1 comprising the amino acid sequence set forth in Figure 1 wherein amino acid position 358 is substituted with an amino acid selected from the group consisting of tryptophan, alanine, asparagine, aspartic acid, cysteine, glutamine, glutamic acid, glycine, histidine, isoleucine, lysine, methionine, phenylalanine, proline, serine, threonine, tyrosine, and valine.

6. The analogue of claim 1 comprising the amino acid sequence set forth in Figure 1 with leucine at amino acid position 358 substituted with tryptophan.

7. The analogue of claim 2 comprising the sequence set forth in Figure 1 wherein amino acids Thr-Leu-Leu-Ser-Ala-Leu at positions 356 to 361 are substituted with amino acids Ile-Pro-Xxx-Ser-Ile-Pro, wherein Xxx is selected from the group consisting of methionine, tryptophan, alanine, asparagine, aspartic acid, cysteine, 10 glutamine, glutamic acid, glycine, histidine, isoleucine, lysine, phenylalanine, proline, serine, threonine, tyrosine, and valine.

8. An analogue of claims 1, 2, or 3 optionally comprising an N-terminal extension selected from the group 15 consisting of methionine-alanine-serine and alanine-serine.

9. An analogue of claim 3 comprising the nucleotide sequence set forth in Figure 1 wherein amino acid positions 356-361 are Ile-Pro-Xxx-Ser-Ile-Pro and wherein amino acid position is methionine.

20 10. An analogue of claim 1 comprising the nucleotide sequence set forth in Figure 1 wherein the nucleotides coding for with leucine at amino acid position 358 substituted with the nucleotides coding for tryptophan.

11. The analogue of claim 2 comprising the 25 nucleotide sequence set forth in Figure 1 wherein nucleotides coding for amino acids Thr-Leu-Leu-Ser-Ala-Leu at positions 356 to 361 are substituted with nucleotides coding for amino acids Ile-Pro-Xxx-Ser-Ile-Pro, wherein Xxx is selected from the group consisting of methionine, 30 tryptophan, alanine, asparagine, aspartic acid, cysteine, glutamine, glutamic acid, glycine, histidine, isoleucine,

lysine, phenylalanine, proline, serine, threonine, tyrosine, and valine.

12. The analogue of claim 11 wherein the amino acid Xxx is methionine.

5 13. A purified nucleic acid sequence coding for an analogue of human wild type  $\alpha$ -1-antichymotrypsin wherein the amino acid corresponding to the leucine at amino acid position 358 of human wild-type  $\alpha$ -1-antichymotrypsin is substituted with an amino acid selected from the group  
10 consisting of tryptophan, alanine, asparagine, aspartic acid, cysteine, glutamine, glutamic acid, glycine, histidine, isoleucine, lysine, methionine, phenylalanine, proline, serine, threonine, tyrosine, and valine.

14. A purified nucleic acid sequence of an  
15 analogue of human wild type  $\alpha$ -1-antichymotrypsin wherein nucleic acids coding the amino acids corresponding to the amino acids Thr-Leu-Leu-Ser-Ala-Leu at positions 356 to 361 of wild-type  $\alpha$ -1-antichymotrypsin are substituted with nucleic acids coding for amino acids Ile-Pro-Xxx-Ser-Ile-  
20 Pro, wherein Xxx is selected from the group consisting of methionine, tryptophan, alanine, asparagine, aspartic acid, cysteine, glutamine, glutamic acid, glycine, histidine, isoleucine, lysine, phenylalanine, proline, serine, threonine, tyrosine, and valine.

25 15. The purified nucleic acid sequence of claim 14 wherein the amino acid Xxx is methionine.

16. The purified nucleic acid sequence of claims  
13, 14, or 15 optionally having an N-terminal extension selected from the group consisting of methionine-serine-  
30 alanine and alanine-serine.

17. The nucleic acid sequence of claim 1 wherein said human wild type  $\alpha$ -1-antichymotrypsin nucleic acid sequence comprises the sequence set forth in Figure 1.

18. An analogue of human wild type  $\alpha$ -1-  
5 antichymotrypsin wherein the analogue has a sequence substantially identical to human wild type  $\alpha$ -1-antichymotrypsin and an N-terminal extension selected from the group consisting of methionine, alanine and serine; and alanine and serine.

10 19. The analogue of human wild type  $\alpha$ -1-antichymotrypsin of claim 15 wherein human wild type  $\alpha$ -1-antichymotrypsin has the amino acid sequence set forth in Figure 1.

20. A purified nucleic acid sequence coding for  
15 an analogue of human wild type  $\alpha$ -1-antichymotrypsin wherein the analogue has a sequence substantially identical to wild type  $\alpha$ -1-antichymotrypsin and an N-terminal extension selected from the group consisting of methionine, alanine and serine; and alanine and serine.

20 21. The nucleic acid sequence of claim 20 wherein said nucleic acid sequence of human wild type  $\alpha$ -1-antichymotrypsin comprises the sequence set forth in Figure 1.

22. An expression vector comprising the nucleic  
25 acid sequence of the analogue of claim 1.

23. An expression vector comprising the nucleic acid sequence of the analogue of claim 2.

24. An expression vector comprising the nucleic acid sequence of the analogue of claim 3.

25. An expression vector comprising the nucleic acid sequence of the analogue of claim 5.

26. A host cell capable of expressing the nucleic acid sequence of the analogue of claim 1.

5 27. A host cell capable of expressing the nucleic acid sequence of the analogue of claim 2.

28. A host cell capable of expressing the nucleic acid sequence of the analogue of claim 3.

10 29. A host cell capable of expressing the nucleic acid sequence of the analogue of claim 5.

30. A cell culture capable of expressing  $\alpha$ -1-antichymotrypsin wherein the amino acid corresponding to the leucine at amino acid position 358 of wild-type  $\alpha$ -1-antichymotrypsin is substituted with an amino acid selected  
15 from the group consisting of tryptophan, alanine, asparagine, aspartic acid, cysteine, glutamine, glutamic acid, glycine, histidine, isoleucine, lysine, methionine, phenylalanine, proline, serine, threonine, tyrosine, and valine, obtained by transforming a cell with an expression  
20 vector comprising the nucleic acid sequence set forth in Figure 1, wherein said vector further comprises nucleic acids coding for an amino acid selected from the group consisting of tryptophan, alanine, asparagine, aspartic acid, cysteine, glutamine, glutamic acid, glycine,  
25 histidine, isoleucine, lysine, methionine, phenylalanine, proline, serine, threonine, tyrosine, and valine at amino acid position 358.

31. A cell culture capable of expressing  $\alpha$ -1-antichymotrypsin wherein the amino acid corresponding to  
30 Thr-Leu-Leu-Ser-Ala-Leu at positions 356 to 361 of wild-type  $\alpha$ -1-antichymotrypsin are substituted with amino acids

Ile-Pro-Xxx-Ser-Ile-Pro, said  $\alpha$ -1-antichymotrypsin obtained by transforming a cell with an expression vector comprising the sequence set forth in Figure 1, wherein said vector further comprises nucleic acids coding for Ile-Pro-Xxx-Ser-  
5 Ile-Pro at amino acid positions 356-361, and Xxx is selected from the group consisting of tryptophan, alanine, asparagine, aspartic acid, cysteine, glutamine, glutamic acid, glycine, histidine, isoleucine, lysine, phenylalanine, proline, serine, threonine, tyrosine, and  
10 valine.

32. A cell culture of claim 31 wherein the amino acid Xxx is methionine.

33. A protein preparation comprising the analogue of human  $\alpha$ -1-antichymotrypsin of claim 1.

15 34. A protein preparation comprising the analogue of human  $\alpha$ -1-antichymotrypsin of claim 2.

35. A protein preparation comprising the analogue of human  $\alpha$ -1-antichymotrypsin of claim 3.

20 36. A protein preparation comprising the analogue of human  $\alpha$ -1-antichymotrypsin of claim 5.

37. A method of inhibiting chymase comprising contacting said chymase with an effective amount of the analogue of human  $\alpha$ -1-antichymotrypsin of claims 1, 2, or  
25 3.

38. A method of inhibiting chymase comprising contacting said chymase with an effective amount of the analogue of human  $\alpha$ -1-antichymotrypsin of claim 5.

39. A method of using an analogue of human wild  
30 type  $\alpha$ -1-antichymotrypsin to inhibit chymase activity

comprising the step of contacting said chymase with an effective amount of said analogue, said analogue having the amino acid corresponding to the leucine at amino acid position 358 of wild-type  $\alpha$ -1-antichymotrypsin substituted 5 with an amino acid selected from the group consisting of tryptophan, alanine, asparagine, aspartic acid, cysteine, glutamine, glutamic acid, glycine, histidine, isoleucine, lysine, methionine, phenylalanine, proline, serine, threonine, tyrosine, and valine.

10 40. A method of using an analogue of human wild type  $\alpha$ -1-antichymotrypsin to inhibit chymase activity comprising the step of contacting said chymase with an effective amount of said analogue, said analogue having the amino acids corresponding to the amino acids Thr-Leu-Leu-15 Ser-Ala-Leu at positions 356 to 361 of wild-type  $\alpha$ -1-antichymotrypsin are substituted with amino acids Ile-Pro-Xxx-Ser-Ile-Pro, wherein Xxx is selected from the group consisting of tryptophan, alanine, asparagine, aspartic acid, cysteine, glutamine, glutamic acid, glycine, histidine, isoleucine, lysine, phenylalanine, proline, serine, threonine, tyrosine, and valine.

20 41. A method of claim 40 wherein the amino acid Xxx is methionine.

25 42. A method of using an analogue of human wild type  $\alpha$ -1-antichymotrypsin to inhibit chymase activity comprising the step of contacting said chymase with an effective amount of said analogue, said analogue having the amino acid corresponding to the leucine at amino acid position 358 of wild-type  $\alpha$ -1-antichymotrypsin substituted 30 with tryptophan.

43. A composition comprising an effective amount of analogue of human wild type  $\alpha$ -1-antichymotrypsin in a pharmaceutically acceptable carrier, said analogue

having the amino acid corresponding to the leucine at amino acid position 358 of wild-type  $\alpha$ -1-antichymotrypsin substituted with an amino acid selected from the group consisting of tryptophan, alanine, asparagine, aspartic acid, cysteine, glutamine, glutamic acid, glycine, histidine, isoleucine, lysine, methionine, phenylalanine, proline, serine, threonine, tyrosine, and valine.

44. A composition comprising an effective amount of an analogue of human wild type  $\alpha$ -1-antichymotrypsin and a pharmaceutically acceptable carrier, said analogue having the amino acids corresponding to the amino acids Thr-Leu-Leu-Ser-Ala-Leu at positions 356 to 361 of wild-type  $\alpha$ -1-antichymotrypsin are substituted with amino acids Ile-Pro-Xxx-Ser-Ile-Pro, wherein Xxx is selected from the group consisting of tryptophan, alanine, asparagine, aspartic acid, cysteine, glutamine, glutamic acid, glycine, histidine, isoleucine, lysine, phenylalanine, proline, serine, threonine, tyrosine, and valine.

20 45. The composition of claim 44 wherein the amino acid Xxx is methionine.

46. Use of an analogue of human  $\alpha$ -1-antichymotrypsin wherein the amino acids corresponding to Thr-Leu-Leu-Ser-Ala-Leu at positions 356 to 361 of wild-type  $\alpha$ -1-antichymotrypsin are substituted with Ile-Pro-Met-Ser-Ile-Pro in the preparation of a medicament for the treatment of inflammation of the lung.

25 47. The use of claim 46, wherein said inflammation results from aspiration of an acidic substance.

30 48. The use of claim 47, wherein the acidic substance is stomach contents.

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49. The use of claim 47 wherein the acidic substance is smoke.

50. The use of claim 46 wherein said inflammation results from infection by a pathogen.

5 51. The use of claim 50 wherein said pathogen is a gram-negative bacterium.

52. Use of an analogue of human  $\alpha$ -1-antichymotrypsin wherein the amino acid at position 358 is selected from the group consisting of tryptophan, alanine, 10 asparagine, aspartic acid, cysteine, glutamine, glutamic acid, glycine, histidine, isoleucine, lysine, methionine, phenylalanine, proline, serine, threonine, tyrosine, valine, and arginine in the preparation of a medicament for the treatment of reperfusion injury.

15 53. Use of an analogue of human  $\alpha$ -1-antichymotrypsin wherein the amino acid at position 358 is selected from the group consisting of tryptophan, alanine, asparagine, aspartic acid, cysteine, glutamine, glutamic acid, glycine, histidine, isoleucine, lysine, methionine, 20 phenylalanine, proline, serine, threonine, tyrosine, valine, and arginine in the preparation of a medicament for the treatment or prevention of blood clots.

54. Use of an analogue of human  $\alpha$ -1-antichymotrypsin wherein the amino acid at position 358 is 25 selected from the group consisting of tryptophan, alanine, asparagine, aspartic acid, cysteine, glutamine, glutamic acid, glycine, histidine, isoleucine, lysine, methionine, phenylalanine, proline, serine, threonine, tyrosine, valine, and arginine in the preparation of a medicament for 30 the treatment of inflammation of the lung.

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55. The use of any one of claims 52, 53, or 54,  
wherein said amino acid position 358 is arginine.

56. The use of any one of claims 52, 53, or 54,  
wherein said amino acid position 358 is tryptophan.

5 57. The use of any one of claims 52, 53, or 54,  
wherein said amino acid position 358 is phenylalanine.

1/6

10	20	30	40	50	
CTC TGC CTC CCT AAC AGC CCA CTT GAC GAG GAC ATT CTC ACC CAG GAG AAC CAA					
Ile Cys His Pro Asn Ser Pro Leu Asp Glu Glu Asn Leu Thr Gln Glu Asn Gln					
60	70	80	90	100	
GAC CGA GGG ACA CAC GTG GAC CTC GGA TTA GCC TCC CCC AAC CTC GAC TTC GCT					
Asp Arg Gly Thr His Val Asp Leu Gly Leu Ala Ser Ala Asn Val Asp Phe Ala					
110	120	130	140	150	160
TTC ACC CTG TAC AAG CAG TTA GTC CTC AAG GCC CCT GAT AAC ATT GTC ATC TCC					
Phe Ser Leu Tyr Lys Gln Leu Val Leu Pro Asp Lys Asn Val Ile Phe					
170	180	190	200	210	
TCC CCA CTG AGC ATC TCC ACC GCC TGC TCC TGT GCG CCC CAT AAT					
Ser Pro Leu Ser Ile Ser Thr Ala Leu Ala Phe Leu Ser Leu Gly Ala His Asn					
220	230	240	250	260	270
ACC ACC CTG ACA GAG ATT CTC AAA GGC CTC AAC CTC ACG GAG ACT TCT					
Thr Thr Leu Thr Glu Ile Leu Lys Gly Leu Lys Phe Asn Leu Thr Glu Thr Ser					
280	290	300	310	320	
GAG GCA GAA ATT CAC CAG AGC TTC CAG CAC CTC CTC CGC ACC CTC AAT CAG TCC					
Glu Ala Glu Ile His Gln Ser Phe Gln His Leu His Leu Arg Thr Ile Asn Gln Ser					

Fig. 1a

330                   340                   350                   360                   370  
 AGC GAT GAG CTG CAG CTC AGT ATG GGA AAT GCC ATG TTT GTC AAA GAG CAA CTC  
 Ser Asp Glu Leu Gln Leu Ser MET Gly Asn Ala MET Phe Val Lys Glu Gln Leu  
 380                   390                   400                   410                   420                   430  
 AGT CTG CTG GAC AGG TTC ACG GAG GAT GCC AGG CAG AGG CTC TAT GGC TCC GAG GCC  
 Ser Leu Leu Asp Arg Phe Thr Glu Asp Ala Lys Arg Leu Tyr Gly Ser Glu Ala  
 440                   450                   460                   470                   480  
 TTT GCC ACT GAC TTT CAG GAC TCA GCT GCA GCT GCT AAC GAC TAC  
 Phe Ala Thr Asp Phe Gln Asp Ser Ala Ala Lys Lys Leu Ile Asn Asp Tyr  
 490                   500                   510                   520                   530                   540  
 GTG AAG AAT GGA ACT AGG GGG AAA ATC ACA GAT CTG ATC AAG GAC CTT GAC TCG  
 Val Lys Asn Gly Thr Arg Gly Lys Ile Thr Asp Leu Ile Lys Asp Leu Asp Ser  
 550                   560                   570                   580                   590                   640  
 CAG ACA ATG ATG GTC CTC GTC GAT TAC ATC TTC TTT AAA GCC AAA TGG GAG ATG  
 Gln Thr MET MET Val Leu Val Asn Tyr Ile Phe Phe Lys Ala Lys Tyr Glu MET  
 600                   610                   620                   630  
 CCC TTT GAC CCC CAA GAT ACT CAT CAG TCA AGG TTC TAC TTG AGC AAG AAA AAG  
 Pro Phe Asp Pro Gln Asp Ser Arg Phe Tyr Leu Ser Lys Lys Lys

*Fig. 1b*

650            660            670            680            690            700  
 TGG GTA ATG CTC CCC ATG ATG ACT TGC CAT CAC CTC ACT ATA CCA TAC TGC TGG  
 Trp Val Met Pro Met Ser Leu His His Leu Thr Ile Pro Tyr Phe Arg  
  
 710            720            730            740            750  
 GAC GAG CTC CTC TCC TGC ACC GTC GTC GAG CTC ACA AAG TAC GCA GGC AAT GCC ACC  
 Asp Glu Glu Leu Ser Cys Thr Val Val Glu Leu Lys Tyr Thr Gly Asn Ala Ser  
  
 760            770            780            790            800            810  
 GCA CTC TCC ATC CTC CCT GAT CAA GAC MAG ATG GAG GAA GTG GAA GCC ATG CTG  
 Ala Leu Pro Asp Gln Asp Leu Pro Asp Gln Asp Ile Phe Ile Lys Met Glu Val Glu Ala Met Leu  
  
 820            830            840            850            860  
 CTC CCA GAG ACC CTCG AAG CGG TGG AGA GAC TCT CTG GAG TTC AGA GAG ATA GGT  
 Leu Pro Glu Thr Leu Lys Arg Trp Arg Asp Ser Leu Glu Phe Arg Glu Ile Gly  
  
 870            880            890            900            910  
 GAG CTC TAC CTG CCA AAG TTT TCC ATC TCG AGG GAC TAT AAC CTC AAC GAC ATA  
 Glu Leu Tyr Leu Pro Lys Phe Ser Ile Ser Arg Asp Tyr Asn Leu Asn Asp Ile  
  
 920            930            940            950            960            970  
 CTT CTC CAG CTC GTC GGC ATT GAG GAA GCC TTC ACC ACC AAG CCT GAC CTG TCA GGC  
 Leu Leu Gln Leu Gly Ile Glu Ala Phe Thr Ser Lys Ala Asp Leu Ser Gly

**Fig. 1c**

980                    990                    1000                    1010                    1020  
 ATC ACA GGG GCC AGG AAC CTA GCA GTC TCC CAG GTC CAT AAG GCT GTG CTT  
 Ile Thr Gly Ala Arg Asn Leu Ala Val Ser Gln Val Val His Lys Ala Val Leu

1030                    1040                    1050                    1060                    1070                    1080  
 GAT GTC TTT GAG GGC ACA GAA GCA TCT GGT GCC ACA GCA GTC AAA ATC ACC  
 Asp Val Phe Glu Glu Gly Thr Glu Ala Ser Ala Ala Thr Ala Val Lys Ile Thr  
 349 350

1090                    1100                    1110                    1120                    1130  
 CTC CTT TCT GCA TTA GTC GAG ACA AGG ACC ATT GTG CGT TTC AAC AGG CCC TTC  
 Leu Leu Ser Ala Leu Val Glu Thr Arg Thr Ile Val Arg Phe Asn Arg Pro Phe

1140                    1150                    1160                    1170                    1180  
 P<sub>1</sub> P<sub>1</sub>  
 CTC ATG ATC ATT GTC CCT ACA GAC ACC CAG AAC ATC TTC TTC ATG AGC AAA GTC  
 Leu MET Ile Ile Val Pro Thr Asp Thr Gln Asn Ile Phe Phe MET Ser Lys Val

1190                    1200                    1210                    1220                    1230                    1240  
 ACC ATT CCC AAG CAA GCC TAG AGC TGG CCA TCA ACC AGT GGG GCT CTC AGT AAG  
 Thr Asn Pro Lys Gln Ala --- Ser Leu Pro Ser Ser Gly Ala Leu Ser Lys

**Fig. 1d**

1250	1260	1270	1280	1290
GAA CTT GGA ATG CAA GCT GGA TGC CTC GGT CTC TGG CAC AGC CTC CCC CCT GTC				
Glu Leu Gly MET Gln Ala GLY Cys Leu GLY Leu Trp His Ser Leu Ala Pro Val				
1300	1310	1320	1330	1340
CAC CGA GTG GCC ATG GCA TGT GTC GCC CTC TCT GCT TAT CCR TGG AAG GTG ACA				
His Arg Val Ala MET Ala Cys Val Ala Leu Ser Ala Tyr Pro Trp Lys Val Thr				
1360	1370	1380	1390	1400
GCG ATT CCC TGT GTC GCT CTC ACA TGC ACA GGG GCC CAT GGA CTC TTC AGT CTG				
Ala Ile Pro Cys Val Ala Leu Thr Cys Thr GLY Ala His GLY Leu Phe Ser Leu				
1410	1420			
GAG GGT CCT GGG CCT CCT GGA ATT				
Glu Gly Pro Gly Pro Pro Gly Ile				

**Fig. 1e**

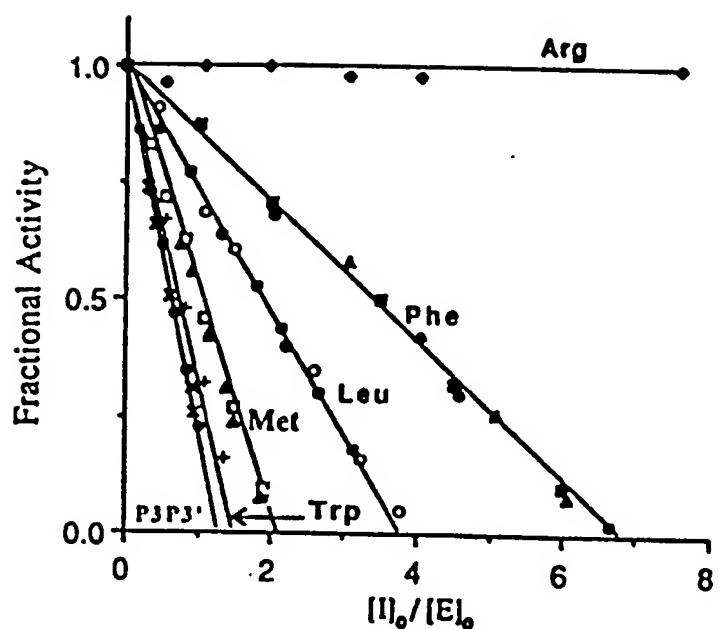


FIGURE 2

**INTERNATIONAL SEARCH REPORT**

In international application No.  
PCT/US94/04703

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC(5) :Please See Extra Sheet.

US CL :530/350, 380, 395; 435/69.2, 70.3, 252.3, 320.1; 514/2, 8

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 530/350, 380, 395; 435/69.2, 70.3, 252.3, 320.1; 514/2, 8

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Please See Extra Sheet.

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US, A, 5,079,336 [RUBIN ET AL] 07 January 1992, Figures 1 and 2, cols. 3-16.	1, 4, 5, 13, 22, 25, 26, 29, 30, 33, 36, 43, 53, 55 and 57
X	US, A, 5,266,465, [RUBIN ET AL] 30 November 1993, Figures 1 and 2, cols. 3-16, References cited.	1, 4, 5, 13, 22, 25, 26, 29, 30, 33, 36, 43, 53, 55, 57
X	The Journal of Biological Chemistry, Volume 268, Number 31, issued 05 November 1993, N.M. Schechter et al, "Reaction of Human Chymase with Reactive Site Variants of alpha-1- Antichymotrypsin", pages 23626-23633, see entire article.	1-7, 13-15, 22-42
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Y		33-36, 43-57

Further documents are listed in the continuation of Box C.  See patent family annex.

• Special categories of cited documents:	
"A" document defining the general state of the art which is not considered to be of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E" earlier document published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O" document referring to an oral disclosure, use, exhibition or other means	"Z" document member of the same patent family
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search	Date of mailing of the international search report
20 JULY 1994	AUG 05 1994

Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer WILLIAM W. MOORE <i>Jill Warden for</i> Telephone No. (703) 308-0196
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## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US94/04703

## C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 5,134,119 [LEZDEY JOHN ET AL] 28 July 1992, cols. 3-6.	33-36, 52-57
Y	US, A, 5,215,965 [LEZDEY ET AL] 01 June 1993, cols. 1-5.	33-36, 46-51, 54, 56, 57
Y	US, A, 5,290,762 [LEZDEY ET AL] 01 March 1994, cols. 1-5.	33-36, 46-51, 54-57
Y	The Journal of Biological Chemistry, Volume 266, Number 29, issued 15 October 1991, A. Kinoshita et al, "Multiple Determinants for the High Substrate Specificity of an Angiotensin II-forming Chymase from the Human Heart", pages 19192-19197, see pages 19193-19197.	52, 53, 55-57
A	The Journal of Biological Chemistry, Volume 264, Number 35, issued 15 December 1989, N.M. Schechter et al, "Reaction of Human Skin Chymotrypsin-like Proteinase Chymase with Plasma Proteinase Inhibitors", pages 21308-21315.	4, 37-39
A	The Journal of Biological Chemistry, Volume 265, Number 2, issued 15 January 1990, H. Rubin et al, "Cloning, Expression, Purification, and Biological Activity of Recombinant Native and Variant Human alpha-1-Antichymotrypsins, pages 1199-1207.	1, 4, 5, 13, 22, 25, 26, 29, 30, 33, 36
A	L.B. Schwartz, Ed., Neutral Proteases of Mast Cells, Monographs in Allergy, Volume 27, published 1990 by Karger, (Basel, Switzerland) pages 114-131.	4, 37-39
A	European Journal of Biochemistry, Volume 194, Number 1, issued 26 November 1990, A.J. Schulze et al, "Structural transition of alpha-1-antitrypsin by a peptide sequentially similar to $\beta$ -strand s4A", pages 51-56.	2-4, 7
A	Biological Chemistry Hoppe-Seyler, Volume 372, Number 1, issued January 1991, K. Rolka et al, "Chemical Synthesis of New Trypsin, Chymotrypsin and Elastase Inhibitors by Amino-Acid Substitutions in a Trypsin Inhibitor from Squash Seeds (CMT III)", pages 63-68.	2, 3, 7
A	Journal of Molecular Biology, Volume 218, Number 3, issued 05 April 1991, U. Baumann et al, "Crystal Structure of Cleaved Human alpha-1-Antichymotrypsin at 2.7 $\text{\AA}$ Resolution and Its Comparison with Other Serpins", pages 595-606.	1, 2, 5, 7

## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US94/04703

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	The Journal of Biological Chemistry, Volume 267, Number 27, issued 25 September 1992, I. Björk et al, "Kinetic Characterization of the Substrate Reaction Between a Complex of Antithrombin with a Synthetic Reactive-Bond Loop Tetradecapeptide and Four Target Proteinases of the Inhibitor", pages 19047-19050.	2, 7
A	Archives of Dermatological Research, Volume 285, Number 4, issued April 1993, I.T. Harvima et al, "Mast cell tryptase and chymase in developing and mature psoriatic lesions", pages 184-192.	4, 37-39, 43
X	The Journal of Biological Chemistry, Volume 268, Number 31, issued 05 November 1993, B.S. Cooperman et al, "Antichymotrypsin Interaction with Chymotrypsin", pages 23616-23625, see especially page 23617.	8, 16, 18, 20, 21

**INTERNATIONAL SEARCH REPORT**International application No.  
PCT/US94/04703**Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)**

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1.  Claims Nos.: because they relate to subject matter not required to be searched by this Authority, namely:
  
2.  Claims Nos.: 9-12, 17 and 19 because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:  

Please See Extra Sheet.
  
3.  Claims Nos.: because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

**Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows:

1.  As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
  
2.  As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
  
3.  As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
  
4.  No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

**Remark on Protest**  

The additional search fees were accompanied by the applicant's protest.

No protest accompanied the payment of additional search fees.

**INTERNATIONAL SEARCH REPORT**

International application No.  
PCT/US94/04703

**A. CLASSIFICATION OF SUBJECT MATTER:**

IPC (5):

C12N 15/09, 15/15, 15/63, 15/70, 15/79; C12P 21/02; C07K 3/00, 15/14; A61K 37/64

**B. FIELDS SEARCHED**

Electronic data bases consulted (Name of data base and where practicable terms used):

DIALOG databases: Derwent Biotechnology Abstracts, Current Biotechnology Abstracts, CA Search, Biosis Previews, Derwent World Patent Index, Medline, Agricola, and APS.

Search terms: chymase, antichymotrypsin, serpin, protease inhibitor, amino acid and substitut? or replac?, analog? or mutein or mutant or mutat?

**BOX I. OBSERVATIONS WHERE CLAIMS WERE FOUND UNSEARCHABLE**

2. Where no meaningful search could be carried out, specifically:

Antichymotrypsin analogues of claims 1-3, from which claims 9-12 and 17 depend, consist of amino acids and comprise no nucleotide sequences therein. Claim 19 describes an analogue of antichymotrypsin having a specific amino acid sequence yet depends from a claim describing a nucleotide sequence. Thus the claims are indefinite and not susceptible of a meaningful search.